SOUTHWEST FISHERIES CENTER

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REPORT OF WORKSHOP: FACTORS CONTROLLING MOVEMENTS OF PURSE-SEINERS IN THE EASTERN TROPICAL PACIFIC OCEAN: TUNA VESSEL OBSERVER PERCEPTIONS 12 AUGUST 1987

by

Elizabeth F. Edwards

ADMINISTRATIVE REPORT LJ-88-26

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ABSTRACT

Researchers at the Southwest Fisheries Center (SWFC), National Marine Fisheries Service (NMFS) are developing a mathematical model to simulate the process of collecting tuna vessel observer data (TVOD) by scientific observers placed aboard tuna purse-seiners fishing in the eastern tropical Pacific Ocean (ETP). To aid in model development, several experienced observers were asked to participate with several mathematical modelers in a workshop at SWFC. Observers were asked to describe their perceptions of the factors that control fishing activities, and in particular, search tracks, of tuna purse-seiners in the ETP. This report describes the results of that workshop.

Primary factors include recent fishing success, perceived success of others, price of fish, current status of holds and fuel, advice and information from shore, skipper personality, international composition of the fleet, vessel characteristics, and presence or absence of helicopters.

Because it has received little direct attention but potentially affects the fishery so strongly, searching with helicopters is discussed in a separate appendix.

INTRODUCTION

The National Marine Fisheries Service (NMFS) is developing a computer model to serve as a tool for testing various hypotheses about the relationship between sightings data collected by scientific observers on tuna purse-seiners fishing in the eastern Tropical Pacific Ocean (tuna-vessel observer data; TVOD) and abundances of dolphins affected by the fishery.

In order to interpret the sightings data and to build an appropriately realistic simulation model of the data collection process, it is necessary to understand the factors that affect purse-seiner movements during fishing trips.

One of the best sources of information available to NMFS about those factors are the scientific observers themselves. Although generally not involved themselves in the decision process, observers are constant participants in purse-seiner activities for weeks to months at a time. Also, as part of their job, they tend to have more access to the vessel skipper and more opportunity than most other individuals on the vessel to observe the skipper's decision-making processes.

As part of the model-building process, and preliminary to interviewing the skippers themselves, NMFS researchers responsible for developing the model invited several experienced observers to participate in a half-day workshop to discuss the their experiences and perceptions of the factors that affect movements of tuna purse-seiners as they fish for tuna.

The workshop was held on 12 August 1987 at the Southwest Fisheries Center in La Jolla, CA. Participants in the workshop included

I. Observers:

Dave Cormany	Former Observer; 4 trips, also was gear tech, last trip completed 1985
Dan Driscoll	Observer; 5 trips, 1.5 years, last trip completed August 1987
Al Jackson	Former Observer; 4 trips, 150 sets, last trip 1981
Brian Ravitch	Observer; 16 trips, more than 1000 days at sea on seiners, last trip completed August 1987.

Randy Rasmussen	Former Observer; 9 trips, more than 890 days at sea on seiners, last trip completed in 1984
John Young	Former Observer; 5 trips, Fleet Contact, Southwest Regional Office

II. Modelers:

Doug DeMaster	Wildlife Biologist, Southwest Fisheries Center
Steve Reilly	Fishery Biologist, Southwest Fisheries Center; former observer (2 trips, 1973)
Pierre Kleiber	Fishery Biologist, Southwest Fisheries Center
Jacquie McGlade	Professor, Dartmouth College, University of Cambridge, Cambridge, England.
Elizabeth Edwards	Operations Research Analyst, Southwest Fisheries Center

The meeting agenda was organized around a hypothetical fishing trip (Appendix 1). For each section of the agenda, observers were asked to comment on and discuss the factors that they perceived to influence the activities of purse-seiners during fishing trips.

Because the amount of information presented was extensive, and the presentation style informal, the entire meeting was recorded on audio tape. The major factors and influences discussed by the observers are described below, derived from transcribed versions of the tapes.

WORKSHOP RESULTS

Although the workshop was organized around the usual itinerary of a fishing trip, this presentation of the observer's comments is organized instead in a form more amenable to codifying the comments into the simulation model. Aspects of the discussion that are not directly relevant to building the model (e.g., advice about developing interview forms) are omitted.

Factors are organized into 2 general categories: I) factors internal and II) factors external to the tuna fishery. Internal factors are caused by the fishery itself. External factors affect the fishery but are not caused by it. Internal factors are further categorized into factors characteristic of single vessels and factors characteristic of groups of vessels.

Examples of single vessel characteristics include vessel capacity, searching technology, and skipper personality. Examples of group factors are international composition of the fleet and code groups. Examples of external factors are the current price of different types of fish, influence of advice from shore (e.g., advice from fathers on shore to sons at sea) and environmental characteristics such as season, weather, and distribution of tuna and dolphin.

As with any categorization scheme, alternative allocations and alternative schemes exist. The set presented here was selected as optimum for building this particular simulation model because model it makes clear the distinctions between the various causal factors affecting the fishery, and the relationships between those factors.

I) Internal Factors

A) Single vessel factors

Single-vessel characteristics that affect vessel movements, roughly in order of importance, include 1) skipper personality, 2) searching technology, 3) recent success rate, 4) vessel capacity (tonnage of fish storable), and 5) gear technology (e.g., ring stripper and speed with which sets can be completed).

1) Skipper personality affects vessel movements by causing the vessel to be more or less likely to strike out alone into new areas versus remaining with or following other vessels. Successful skippers, in the observers' opinion, are those that have been consistently persistent and keep at it, depending little on vague "feelings". Highly motivated skippers will make four or five trips per year; the less motivated, only about three.

Relatively few skippers are willing to go out and search completely alone. Skippers usually prefer to search in co-operation with one or two other vessels. In general, a few skippers always do well; many other skippers try to shadow these "highliner skippers", and break their codes. "Highliner" technically refers to a ship having a capacity of at least 1000 tons but the term is used also for the skipper of such a vessel, if particularly successful.

Being a skipper is not a temporary or lightly held position. Successful skippers make a lot of money, and tend to stay in the position as a career. These factors have at least two implications for vessel movements. First, personal preferences for particular strategies should persist for some time in the fleet. Second, strategies of skippers may be relatively consistent within the entire international fleet because many

tuna skippers are from the US and learned their trade in the US fleet, before switching to other registries.

A skipper's propensity to be a risk-taker or conservative is influenced at least in part by whether he owns his own vessel, or is working for a company. The impressions of observers were that skippers who own their own vessels tend to take more risks. Skippers who work for a company must produce consistently, and are thus less likely to risk present (albeit perhaps small) catches for larger (but uncertain) catches in the future. These skippers will tend more to follow the crowd.

2) Searching technology strongly affects vessel movements by making some searching strategies more or less effective. The two most important searching tools are, in order, 1) helicopters, and 2) high power (20X - 25X) binoculars. Helicopters are a relatively recent innovation, and have had very significant effects on the activities of purse-seiners. Considerable time was spent discussing their use. A separate section is devoted to summarizing observer comments on searching with helicopters (Appendix I).

The number and placement of the binoculars is important. Traditionally, 2 pairs of 20X binoculars were placed on the flying bridge, augmented by a crewman with hand held binoculars in the crow's nest. More recently, both the bridge and the crow's nest tend to be equipped with 25X binoculars. Also more recently, a fourth 25X pair is placed on a platform midway up the mast. These glasses on the mast and particularly in the crow's nest, placed higher than those on the flying bridge, significantly increase the searchable area between the ship and the horizon, increasing probability of sightings and thus affecting vessel movements because vessels usually turn toward and investigate any promising sighting.

The increase in searchable area provided by placing 25X binoculars in the crow's nest has resulted in some vessels having sighting rates from this platform equaling or exceeding sighting rates from the ship's helicopter. This is because the major cue for tuna schools is usually birds, and these are seen much more readily from the crow's nest where birds are silhouetted against the horizon, rather than from the helicopter where birds are difficult to see against the water.

3) Recent success rate affects vessel movements by making it more or less likely that a vessel's next action after a set will be to remain in an area, or to leave and seek new fishing grounds. If success is good, vessels will tend to remain, modulated by the skipper's propensity for risk-taking. Vessels will tend to drift in an area at night instead of moving on. If success has been poor, vessels will be more likely to look elsewhere.

4) Vessel capacity affects vessel movements because smaller vessels will tend to set on everything, while vessels with larger holds will tend to wait for potentially larger schools. For larger vessels, small sets are a proportionately greater waste of time and increase the probability of equipment problems. Also, smaller vessels can set in shallower areas, such as local banks. These areas are not accessible to the larger vessels. Smaller vessels (500 ton capacity) may have only 11-12 strips on the purse-seine, versus 15-17 in the nets of larger vessels (1000-1200 ton capacity).

5) Purse-seine gear technology, as well as searching technology, can also affect vessel movements. In particular, the advent of ring-strippers has made it possible for sets to be made in worse weather and to be completed 15-20 minutes sooner than on vessels without these strippers. This means that vessels with ring-strippers may fish in areas and at times not available to other ships, and complete more sets per day with lower mortality of dolphins. As yet, relatively few vessels use these devices, but the practice is spreading. Interpretation of vessel movements may soon depend on information about their use.

Another technological advance in searching has been use of satellite navigation which, by better pin-pointing positions continuously, allows vessels to search more efficiently and move more directly from point to point.

Chronology of Factor Influences:

Leaving Port. Several factors influence a skipper's choice of course and destination leaving port. These include 1) recent information from other purse-seiners at sea, 2) weather, 3) season, 4) location and success of related skippers (related by family or by code group), 5) location of unloading port, and 6) type of fishing preferred.

1) Recent information from other purse seiners affects vessel movements by causing skippers to target or avoid areas recently searched by other vessels. At one time, 40-60% of the fleet will be at sea, transmitting information about fishing conditions. Successful areas will probably be targeted, especially if new and therefore relatively unexploited. Unsuccessful areas will be avoided.

2) Recent weather controls specific directions leaving port because purse seiners cannot set in rough seas. There is no point in heading directly to an area where the vessel will be forced to sit or drift for several unproductive days. Most vessels are now equipped with FAX machines, which provide skippers a constant flow of information about current weather conditions in the ETP.

3) Season affects the direction vessels leave port for the same reason as recent weather (i.e., inability to set in rough seas). During the hurricane season of late summer and fall, when fishing conditions tend to be marginal in the offshore grounds, these area are avoided by tuna vessels.

4) The location and success of other skippers controls direction of vessels leaving port because it is not unusual for 2 skippers to leave for roughly the same area in order to maximize their searching efficiency. Also, before leaving port, skippers will find out all they can about the success rates and recent experiences of skippers at sea. Thus, almost all skippers have chosen a destination upon leaving port.

5) Location of unloading port can control direction leaving port because the two primary unloading ports are located almost 16000 kilometers apart, in American Samoa and Puerto Rico. Simply reaching these ports will consume significant time and fuel. Vessel movements can be constrained by the necessity to conserve sufficient fuel to reach these distant ports. As holds are filled near capacity, vessel movements are more likely to be in the direction of the unloading port, regardless of fishing conditions, than they might be earlier in the trip when holds are less full and fuel reserves greater.

6) Preferring one type of fishing over another. (i.e., log fishing, school fishing or dolphin fishing) influences vessel movements because the different types tend to occur in different areas. Log fishing occurs in areas where water currents concentrate logs and other floating debris. School fishing takes the smaller tuna that tend to occur relatively nearshore. Dolphin fishing occurs both inshore and offshore, but is emphasized offshore.

7) Running to fishing grounds. Once at sea, time must be spent running to the fishing grounds. Usually not more than 7-10 days are spent in this activity. Searching usually begins actively within 2 days after leaving, although this depends strongly on the port. Ships leaving Panama will begin searching within the first day. Ships leaving American Samoa will have several days to run before reaching traditionally good fishing grounds (east of about 140W).

8) Occupying the fishing grounds. Once on the fishing grounds, a number of factors affect vessel movements. These include, among others, the type of fishing and local success rates. Log fishing with beepers placed on logs constrains vessels to remain within about 60 miles of the logs, both to remain in range of the beeper, and to return to the log in a relatively short time. A vessel that has just made a successful set may leave the area to avoid the influx of secondary arrivals attracted by news of the

first vessel's success. Alternatively, a vessel will probably leave an area after three unsuccessful sets.

Time of day is another significant factor affecting seiner activity on the fishing grounds. Early in the day, vessels are much more likely to pass up marginally interesting schools, gambling that the time will be better spent searching for larger schools with a better return on the time invested in setting and retrieving the seine. Later in the day, especially near sunset when searching must cease, seiners are much more likely to set on anything they encounter.

Certain crew members, in particular the deck boss and the crew members with better "eyes" also influence vessel movements on the fishing grounds. The deck boss is in charge of all net operations and controls the time it takes to complete a set. The "eyes" in a crew are the crewmen who are unusually adept at finding cues to schools of tuna. When these men are using the binoculars, the vessel is more likely to see and set on schools, than when other crew members are on watch.

The international composition of the crew can also affect vessel movements. The non-US fraction of the purse-seine fleet is relatively young, so that crews tend to have had less experience. In the early period of international expansion, most of the skippers were from the US. This proportion has been decreasing as the international fleet matures. This change can affect vessel movements and search dynamics because less experienced crews tend to take longer making sets, and have relatively more problems. Time spent searching and distance traveled will be greater than for vessels with more experienced and adept crew.

Differences in behavior of different dolphin species also affects vessel movements, in particular the likelihood of making a set on a sighted school of dolphins. The preferred species is spotted dolphin (Stenella attenuata). These animals "carry" the largest schools of tuna, and their behavior in the net is relatively calm, allowing the fishermen to release them with relatively low mortality. Spinner dolphins (Stenella longirostris), although the second most likely species to carry significant amounts of tuna, are much more excitable. They are more difficult to catch, react poorly to the net, and generally increase the time and risks of each set. Streaker dolphins (Stenella coeruleoalba) and common dolphins (Delphinus delphis) are equally excitable or worse, and carry relatively fewer tuna.

Purse-seiners may completely ignore a given school of tuna associated with the troublesome dolphins, while the same school associated with spotters would elicit a set.

The likelihood that a set will be made on any given school of dolphin is also influenced by skipper personality. Some

skippers set on everything encountered. Others will pass by numbers of schools that appear to carry only small schools of tuna, waiting for one big school despite the fact that the sum of the small schools might have equaled or exceeded the large school finally taken.

The presence of a helicopter also strongly affects the activities of it's associated seiner on the fishing grounds (see also Appendix I). A vessel without a helicopter is constrained to approach and often to wrap a school before the actual tonnage of fish can be assessed. A vessel with a helicopter can (and does) send the helicopter to hover over the school, where the helicopter passengers can see exactly where the tuna are relative to the dolphin. They can also assess directly the tonnage of fish.

9) Returning to port. Vessels return to port primarily because their holds are filled. But returns are also dictated by factors more or less unrelated to catch.

Observers estimated that in the US fleet about half the returning purse-seiners have contracts to unload at certain port before leaving on a trip. The others tend to have representatives on shore that organize contracts while the vessels are fishing at sea, and inform the vessel of a selected port later in the trip. Observers felt that most Mexican vessels unload at the US canneries in Puerto Rico.

Current status of food and fuel stores, needs for repairs, and percent of the holds filled affect cruise tracks by increasing or decreasing the likelihood that vessels will remain in a given area or seek particular new ones. If food or fuel supplies are low, or if the holds are almost full of fish, or if equipment problems require a port call, the direction of search will be constrained by the need to move closer to the nearest (or chosen) port, regardless of environmental conditions or of the success or failure of other vessels.

Another factor causing vessels to return to port before the holds are full is a call from the contracted cannery, requesting immediate offload of fish, rather than waiting until the holds are filled.

Equipment failures can also require returns to port before the holds are full. In many cases equipment problems can be dealt with at sea by trading parts between vessels as they are needed. Because purse-seine nets are very large (3/4 mile long, 350-400 feet deep) vessels carry only one, with some spare net panels for repairs. A serious problem at sea with the net could therefore cause a vessel to return prematurely to port. Observers estimated that mechanical breakdowns may cause un-planned port calls in about 20 out of 100 cruises. But these stops are

usually short compared to unloading, removing the vessel from the search process for only a few days instead of 1-2 weeks.

Near the end of a trip when the holds are almost full and fuel supplies depleted, the skipper will probably concentrate searching in areas on the path to the chosen port, regardless of possibilities of better catches elsewhere.

B) Multiple Vessel Factors

1) International Composition of purse-seine fleet. The mix of nationalities comprising the total international fleet fishing in the ETP influences cruise tracks and activities of individual vessels in several ways. With the passage of the Fishery Management and Conservation Act (the Magnuson Act) by the US in 1978, in effect initiating the 200 mile Exclusive Economic Zone all along the western coast of the Americas, it became necessary to buy licenses to fish in areas that previously had been open to all (primarily US, at first) vessels. Whether certain vessels fish in certain areas is dictated now not only by expectation or experience of fishing success, but also by whether the vessel has invested the $50,000-$60,000 necessary to buy the necessary licenses.

Also, changes in fishing strategies, although not documented, may be occurring as the fleet changes from predominantly US, based in San Diego, CA to predominantly Mexican. In 1975, the total international fleet included about 160 vessels, of which about 100 were US registry. In 1987, only about 30 vessels remained under United States registry. The size of the Mexican fleet has increased dramatically, both due to construction of new ships and purchase of United States vessels. In 1987, the Mexican fleet includes 60-70 vessels. In addition to increasing the size of their fleet, Mexico has also been increasing the average size of the vessels. Venezuela is also increasing the size of her fleet, having 9 vessels fishing in the ETP by 1987.

During the beginning of this expansion, most of the skippers were from the US. Presumably, their fishing strategy remained fairly constant even though they changed nationality of registration. More recently, as non-US skippers have become more common, fishing strategies may have changed. Observers could offer no direct advice about this possibility, but felt it should be investigated.

Equipment differences and differences in requirements and regulations probably are having a much more profound effect on the search tracks and fishing activities of the international fleet. Non-US vessels tend not to have the same level of technology as US vessels. In particular, equipment tends to be

in worse repair, so that sets take longer and mortality is a greater problem.

Non-US vessels also do not have to conform to FCC regulations about radio transmissions, so that communication between code groups may be more effective because more easily hidden from eavesdropping.

The activities of the fleet as a whole have also been changed by the elimination of areal restrictions upon fishing for yellowfin tuna. This closure used to occur in the IATTC's CYRA (Commission Yellowfin Regulatory Area). A prime fishing area relatively nearshore along the coasts of Mexico and Central America, the CYRA supports large numbers of smaller yellowfin (schoolfish).

The CYRA was designed to protect the tuna resource from overfishing. Each year since the mid-1960s, the IATTC has issued a quota on yellowfin catches in the CYRA. Once the quota was reached, vessels had to move "outside the line" to fish on yellowfin. The tuna fleet as a whole generally fished the nearshore CYRA from the beginning of the year in January until the closure occurred in March or April. Subsequently, for the rest of the year, the fleet moved "outside the line" and concentrated more heavily on fishing for the larger yellowfin found with porpoise.

However, since 1980 disagreements between IATTC member nations have prevented the annual quotas from being recognized. Closures have not been instituted, so CYRA closure no longer affects the movements and fishing activities of the purse-seine fleet.

2) Communications. Another major factor affecting vessel movements, particularly search and set activities of the purse-seine fleet, is communications. Communications can take the form of information transfer from one ship to another, or from persons on shore to the ship(s) at sea. One particularly important source of information transfer ship-to-ship is the set of vessel subgroups called code groups. Code groups and shoreside information are discussed individually below in greater detail. Code groups are discussed as internal factors. Shoreside information is discussed as a factor external to the fleet because it affects but is relatively little affected by, activities of the fleet.

Code Groups

Code groups are groups of co-operating vessels which transfer among themselves, exclusive of the rest of the fleet, coded information about fishing success, positions, and any other pertinent information. The groups consist usually of 5 to

15 vessels. Groups may be as large as 35 or as few as 3, but larger groups seem to split up more or less spontaneously when the group becomes "too big".

Code groups are one of the most important factors affecting the analysis of movements of vessels in the fleet. By exchanging information about events in other areas, the movements and activities of a given vessel become dependent on the experiences of the other members of the code group. This confounds the desired direct relationship, for estimates of abundance, between encounters with dolphin schools and the actual abundance of animals. Ships operating in code groups are likely to see more animals than ships that are not co-operating in this manner, because in effect a code-group becomes a super-organism with a greatly expanded field of search.

Thus ships operating in code groups can no longer be considered independent replicate sampling units, because the movements of the ships become dependent on the shared information. Theoretically, analyses might consider the code groups as a single unit, but the identity of code groups tends to be guarded carefully. The information they share is guarded very carefully. Code groups also tend to be fairly dynamic, changing in membership and size from one season to the next, or even from one month to the next.

Code groups exchange coded information from 1 to 3 or more times per day, especially at the end of the day, but also tend to talk informally all day long. Ideally, group members inform one another of what they have caught and where they are. Then the group plots it's next moves. Usually, most of the group will move together, with typically a few renegades (see section on skipper personality) moving off in other directions. The movement is generally in a given direction, but vessels avoid following directly in the path of another, as that area has already been searched.

Most of the observers reported that information is frequently withheld from other code group members. But the current advantage has to be weighed constantly against the future loss of co-operation if the action is detected by the other members of the code group. Generally, most other vessels know or soon find out when a set has been made, but the code groups can delay or facilitate this transfer of information within the fleet.

II) External Factors

A) Shoreside-to-vessel communications. Another factor significantly affecting vessel movements is at best only indirectly related to tuna abundance in the vicinity of the vessel. This is information transmitted to the vessel from

sources based on shore. Two sources are common; relatives of the skipper (often a father, sending advice to his son the skipper), and representatives of canneries or companies owning vessels.

Relatives may affect cruise tracks by offering advice and suggestions based on their shoreside impression of conditions at sea. Companies owning several vessels may direct one or more toward or away from certain areas, where the ship without this interference would have chosen a different track. These track changes may drive the ship either toward or away from concentrations of tuna, independent of the vessel's perception of the probability of making good catches of tuna. The opportunity to unload quickly, or currently high prices at the canneries, may influence a vessel to return early from a trip. Companies with several boats may direct some of a group away from a "hot" area, in order to maximize searching, leaving the remaining vessels to collect the local schools.

The industry representative, by monitoring the cumulative kill and probability of reaching the annual quota for dolphin mortality, also can affect the tracks by suggesting that non-dolphin fishing be emphasized.

B) Environmental conditions and characteristics. Environmental characteristics that affect tuna purse-seiner cruise tracks include physical and chemical signals as well as indications of animal types and behaviors. Physical and chemical signals include 1) local weather, as reflected by sea state, currents, and wind speed and direction, 2) season (expected weather), and 3) appearance and condition of the water mass.

Even moderately poor weather conditions can cause vessels to leave an area, because the dangers of setting the purse-seine means skippers generally do not use helicopters or set nets in bad weather (Beaufort sea states greater than about 4). Skippers will also avoid areas where currents that can tangle the net are known to be common. Because of this, season of the year, in particular the hurricane season, is one of the strongest controls on the movements of tuna purse-seiners. This makes it possible to predict with variable accuracy where the majority of the fleet will be at any given season during the year. Occasionally, vessels will wait up to 2 weeks for weather to clear, if expectations of fishing success are high, but this is quite rare. Factors related to the appearance and condition of water masses include clarity ("dirty" water is good), temperature (over about 85F is bad), and currents (currents are bad because they make it difficult to set the net).

The large-scale warming of El Niño conditions is another factor acting on a seasonal or annual scale that affects where seiners fish. Tuna fishermen feel that the warmer waters associated with an El Niño are poor for finding tuna, and also

make the associated dolphins "wild" so that they are harder to catch and more difficult to handle in the seine.

The behavior and apparent fishery-related changes in the behavior of the different species of dolphins in the ETP also affect the activities of seiners (see other sections). In particular, dolphin schools of all species have become increasingly difficult to catch in recent years, increasing the time and effort requited in both chase and set.

SUMMARY

Cruise tracks followed by purse-seiners searching for schools of tuna in the eastern tropical Pacific Ocean are controlled by a variety of factors. Some factors are specific to an individual vessel, some are due to interactions between groups of vessels, some are due to interactions between vessels and information flow from shore, and some are due to environmental conditions. Factors specific to individual vessels include skipper personality, search technology, recent success rate, vessel capacity, and set technology. Other factors related to the chronology of any given trip by an individual vessel include recent success rate and position of other purse-seiners currently at sea, weather and season of the year, location of unloading port, preferred type of fishing (i.e., log, school, or dolphin fishing), dolphin behavior, and the presence or absence of a helicopter. Influential factors characteristic of groups of purse-seiners include international composition of the fleet and communication between vessels, and between vessels and interests on shore. Environmental factors that affect ship movements include water temperature and clarity, distribution of animals (current and historical) and large-scale weather systems (e.g., El Niño).

The relative importance of all these factors changes with the conditions of each factor, and with the condition of each vessel. But in general, hierarchies of importance can be deduced under the basic assumption that a vessel's primary goal is to catch as many fish as quickly as possible with the least risk (both current AND future) and greatest financial return.

ACKNOWLEDGEMENTS

Thanks are extended to the workshop participants for their time and insightful comments.

APPENDIX I. Using Helicopters to Find Tuna

Most if not all of the larger purse-seiners (greater than 1000 ton capacity) now sail with a helicopter on their decks. About 20 of the current fleet of 33 US tuna purse-seiners have them. This innovation has spread throughout the fishery during the past -10 years, with potentially profound effects on search patterns and on rates of sighting and set by ships with helicopters compared to those without.

Smaller vessels are precluded from this innovation, primarily because they do not have the space required above the pilot house for helicopter landings and storage, but also because a smaller vessel may not be able to support a helicopter financially, given the smaller tonnage possible per trip. Only an inability to meet the continuing expenses of supporting a helicopter will prevent a larger vessel from sailing with one.

In an area fished both by vessels with helicopters and vessels without helicopters, the vessels with helicopters catch many more fish. Vessels without helicopters basically cannot compete successfully in the same area, regardless of size, crew expertise, or other potential advantages.

Searching With Helicopters

The ways in which tuna are sighted and captured have been affected profoundly by this change in searching technology. This has also a direct effect on the data collected by tuna vessel observers. This is both because of differences in the search and set activities of the ship itself, and differences in the way data are collected or presented to the observer. Differences in search and set activities and differences in data collection are discussed in turn below, following a description of differences in helicopter characteristics.

Search procedures using helicopters differ considerably from the traditional method using 2 - 4 pairs of high power (20-25X) binoculars mounted on the flying bridge and on the mast to sight schools or cues to schools of tuna. In particular, cues and spatial patterns of search are different. Using binoculars, the most effective cues to tuna schools of any sort are birds and changes in the texture of the water's surface, indicating the presence of feeding animals below. Using helicopters renders bird cues virtually useless. This is because searching from helicopters places the sighting platform several hundred feet instead of several tens of feet above the water's surface. Birds become much more difficult to see because they are no longer silhouetted against the horizon as they are when seen from the ship's bridge and mast.
However, changes in water texture, splashes from jumping animals, and silver flashes from the tuna schools themselves become much

more visible. For helicopter searching, these events at the water's surface, rather than bird flocks, are the primary cue for schools of tuna.

Search procedures differ also between skippers and between trips. Some skippers use the same search pattern regularly, others use a variety of patterns, still others leave the search pattern to be chosen by the pilot or fish spotter. Some fly arcs in front of the vessel, some fly cross-hatch patterns, other fly spirals. There appears to be no single preferred or obviously optimal pattern.

Spatial patterns of searching differ with helicopters by being much more versatile. Binocular searches are restricted to a forward half circle from amidships to the horizon progressing at about 15 knots. The sighting horizon is about 6 miles, given the deck and mast heights of most tuna seiners. Helicopters, on the other hand, can be directed to fly any number of patterns, can range further from the ship, and have much wider field of view due to their much greater height above the ocean's surface. Distance of search is constrained more by the ability of the ship to get to a sighted school than by the actual range of the helicopter itself.

Another major difference in the search paths is that a ship-based sighting function (the relationship between distance from the ship and probability of sighting a school) probably no longer exists for the helicopter. Although a given helicopter and crew under given sighting conditions will have a characteristic sighting function describing probabilities of sighting schools at given distances from the helicopter as sighting platform, this will bear little if any relationship to the distance between the ship and the sighted school. This has serious implications for using line transect theory to estimate density of dolphins from sightings made from helicopters, unless sufficient data can be collected from each helicopter to characterize the sighting functions and to consistently separate sightings made by the helicopter from those made by the ship.

A second major advantage of using helicopters to fish for tuna, in addition to greatly increasing the searchable area, is that the helicopter provides a perfect platform from which to assess not only the <u>exact</u> location but also the size of the sighted tuna school. Without helicopters, vessels must sight, chase and set on a school before tonnage and sizes of the tuna can be determined. With helicopters the search process is much more efficient. Sets on small schools can be eliminated if desired, and the seine can be positioned much more precisely.

Having a helicopter affects also the types of risks vessels are likely to take. Whereas a smaller purse-seiner may be more likely to risk moving to new areas, the same small vessel will

probably be less likely to risk passing up a relatively small school early in a day's fishing as a gamble that larger schools will be encountered later in the day. This is because smaller vessels can have a successful trip capturing only about 650 tons, whereas the helicopter-seiner must complete a 1000-1200 ton trip. Even small schools can contribute a significant proportion to the tonnage required to complete a trip.

Helicopters do not obviate completely the sighting success of binoculars. Observers estimated that even with helicopters, perhaps 50% of the fish are found by helicopters and 50% by the men on the glasses. A secondary use of the helicopter, especially on vessels that are trying to minimize helicopter costs, is to use the helicopter simply to check out a school seen from the glasses. This saves the ship from wasting time on small schools, while decreasing fuel and repair costs for the helicopter.

Characteristics of Helicopters

The size of helicopters that are used on tuna purse-seine vessels is restricted both by the size of the landing platform and the range that the helicopters need to cover. The helicopters used range from "top of the line Hughes" to "little Bells". Generally the helicopters are fairly small, with relatively restricted range, because there is little point in getting too far from the vessel. This is partially because rescues would take too long, but also because even if a school is sighted, fuel constraints will prevent the helicopter from hovering above the school to hold it, for more than a couple of hours. Sightings far from the vessel late in the day are also to be avoided, because problems with setting and retrieving the seine increase considerably after sunset.

Helicopters are used continuously if possible during daylight hours. They are usually in the air by sunrise and fly 8-9 hours per 12-14 hours of daylight. The helicopters usually have enough fuel for 2-2.5 hours of flight, then return to the vessel for refueling and any repairs needed. These stops will be quite brief (less than 1/2 hour), less if the pilot is not also the mechanic. No one is happy when the helicopter cannot fly. Unless the holds are almost full (e.g., 800 out of 1000 tons loaded), ships will return to port rather than fish without a functioning helicopter.

Helicopter Effects on Inter-Vessel Actions

Having a helicopter also affects inter-vessel activities. "Helicopter wars" do occur, in which helicopters (and vessels) compete for given schools, although the wars occur most often between vessels of different nations and relatively rarely within

code groups, bound again by the need to balance current gains against future needs for co-operation.

These "helicopter wars" occur because of another innovation due to use of helicopters for searching and catching tuna. This is the practice of "holding" a school by hovering over it until the vessel can arrive. Generally, even if the helicopter-seiner is 20 miles from it's hovering helicopter and another vessel is only a couple of miles away, the school beneath the helicopter is considered to "belong to that distant vessel". In practice, whether a vessel raids another's school will depend, as usual, on the skippers perception of the tradeoff between stealing the school at hand and repercussions in the future.

Co-operative search between two or more vessels each with helicopters or between vessels with and without helicopters has not been reported probably because each vessel, despite the code groups, is in fact an individual collecting unit, dependent for survival on its own financial success.

Effects of Helicopter Searching on Data Collection by Observers

Helicopters affect in several ways the quantity and quality of data collected by observers. With helicopters, it is much more likely that schools will go unreported. This is because when helicopters are used to search for cues to tuna schools, it happens frequently that most of the sightings (often over half) will be made by the individuals in the helicopter. The helicopter usually carries only the pilot and one fish spotter, either a crewman or the captain. This means that the observer never sees most of the schools, and must rely on reports from the helicopter. The identity of the fish spotter can profoundly effect the data relayed to the observer. If the fish spotter is a crewman, he will (presumably) report most of what he sees to the captain. If the observer is permitted to listen to the radio transmissions from the helicopter, he will at least gain some information about schools in the area. If the fish spotter is the skipper, the observer may hear little if anything, because there is no one the skipper needs to report his observation to, unless he intends to initiate a chase and set.

Observers reported that one advantage of the fish spotter being the skipper is that without the skipper on board, the observer is more likely to be allowed into the radio room, where he can hear the helicopter communications directly.

A second effect of the skipper flying is that the effort on the glasses may decrease, changing again the relationship between search effort and probability of sighting a school.

A third way in which helicopter searching affects cruise tracks is that vessels will not go to areas where the helicopter

looked and found nothing. Simply studying the cruise tracks of such a vessel will not give a true picture of the effort expended and area searched.

Fourth, helicopters will check out and subsequently ignore schools that observers would have seen or would have had reported if searching had been completely carried out by ship-board binoculars. Estimates of dolphin school size, an important parameter for line transect analysis of dolphin abundance, is therefore biased towards schools that tend to carry large amounts of tuna.

SUMMARY

Searching for tuna with helicopters has changed profoundly the relationship between sightings of tuna and dolphin schools reported by scientific observers, cruise tracks of the vessels, and presumably the true abundance and distribution of tuna and porpoise.

These changes arise both from changes in the search and chase procedures themselves, altering the cruise tracks and time spent fishing by the vessels, and from changes in the way observations are reported to the observer.

APPENDIX II. Workshop Agenda

MEMORANDUM FOR: Participants
Tuna purse-seine fishing Effort
Workshop #1 : observer experiences

FROM: E. Edwards

SUBJECT: AGENDA: WORKSHOP #1.

DATE: 10 August 1987

TUNA PURSE-SEINE FISHING EFFORT:

WORKSHOP #1 - OBSERVER EXPERIENCES

18 August 1987

AGENDA:

I. Introduction.

1:00 - 1:15 PM: Description of objectives
Introductions

II. Discussion of observer experiences during events throughout a "typical cruise" (historical and current).

1:15 - 2:15 PM: Leaving Port
Running to fishing grounds

2:15 - 2:30 PM: Break

2:30 - 3:15 PM: Activities on fishing grounds
(mode, search, chase, set, release)

3:15 - 3:30 PM: Break

3:30 - 4:30 PM: Returning to port
other factors